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Service des pêches et des sciences
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SOME OBSERVATIONS ON HEAVY METAL CONCENTRATION IN NORTHEASTERN NEW BRUNSWICK ESTUARINE SURFICIAL SEDIMENTS

by S. RAY and W. WHITE

This is the first
Technical Report from the
Freshwater and Anadromous Division
Resource Branch
Halifax, Nova Scotia

Ceci est le premier
Rapport Technique de la
Division des eaux douces et
poissons anadromes
Direction de la ressource
Halifax, Nouvelle-Ecosse

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ABSTRACT

Ray, S. and W. White. 1977. Some observations on heavy metal concentration in northeastern New Brunswick estuarine surficial sediments. Freshwater and Anadromous Division, Resource Branch, Fisheries and Marine Service, Dept. of Fisheries and the Environment, Halifax, Nova Scotia. Tech. Rep. No. 696, 30 p.

The salmon-bearing rivers—Miramichi, Nepisiguit and Restigouche—originate in the highly metallogenic region of northeastern New Brunswick. Due to industrial and mining activities in the area, there has been a sharp decline in salmon landings in recent years. An environmental geochemical survey of the river and estuarine sediments of the area was undertaken in the summer of 1973 to assess the baseline data and impact of mining activities. It is concluded that Miramichi and Restigouche rivers are relatively uncontaminated, but the Nepisiguit River system causes concern. Trace-metal levels in the mining effluents on this river should be controlled.

RESUME

Ray, S. and W. White. 1977. Some observations on heavy metal concentration in northeastern New Brunswick estuarine surficial sediments. Freshwater and Anadromous Division, Resource Branch, Fisheries and Marine Service, Dept. of Fisheries and the Environment, Halifax, Nova Scotia. Tech. Rep. No. 696, 30 p.

Les rivières à saumon Miramichi, Nepisiguit et Restigouche prennent leur source dans la région fortement métallogénique du nord-est du Nouveau-Brunswick. En raison des activités industrielles et minières qui ont cours dans la région, les prises de saumon ont diminué de facon considérable au cours des dernières années. Au cours de l'été 1973, on a entrepris une étude environnementale géochimique des sédiments des rivières et des estuaries de la région afin d'évaluer les données de base et l'impact des activités minières. On conclut que les rivières Miramichi et Restigouche sont relativement peu polluées, mais que le réseau fluvial Nepisiguit suscite de l'inquiétude. Il faudrait contrôler le niveau des traces de métal présentes dans les effluents qui se déversent dans cette rivière à partir des mines.

INTRODUCTION

Recently, there has been an increasing awareness of heavy-metal contamination of the environment. Regional, geochemical reconnaissance data have been applied successfully to various aspects of environmental research, including agricultural, pollution, estuarine, fisheries, etc. These geochemical data are effective in predicting the effects of heavy metals on water quality. Research into heavy-metal pollution of estuaries and measurements of heavy-metal concentrations in estuarine sediments can serve as a guide to assess the heavy-metal contamination of surface water, instead of having to conduct the more time-consuming operation of water monitoring itself.

Heavy metals are a serious pollution problem in the aquatic environment, since most of them are toxic to fish. Industrial and urban waste-water discharge into a stream may increase the heavy-metal concentration in the water and also lead to an accumulation in the sediments.

Resource exploitation in northeastern New Brunswick is centered on forestry, fishery and mineral resources of the region. However, the valuable fishing industry has recently been threatened by the deterioration of water quality arising from the other resource-based industry, base-metal mining.

Four of the six basic provincial metallogenic zones occur in northeastern New Brunswick (Montreal Engineering Co. 1973). Of these, the Tobique and Miramichi zones are of particular interest and contain many known copper, zinc, lead and pyrite deposits.

The region contains known deposits in excess of 300 million tons of lead and zinc. Development of the known reserves led to a striking increase in the value of mineral production, which rose from $18.8 million in 1961 to $107.4 million in 1971.

On the other hand, commercial salmon landings in Restigouche, Gloucester and Northumerland counties declined from 501,000 lb in 1969 to 230,000 lb in 1971, while the angling catch fell from 164,000 lb to 68,000 lb during the same period.

There were at the time of sampling three active mining operations in the region:

1. Heath Steele Mines Ltd.
2. Brunswick Mining and Smelting Corporation - No. 12
3. Brunswick Mining and Smelting Corporation - No. 6

Two other mines in the region, Nigadoo River Mines Ltd. and Anaconda American Brass Ltd., suspended their operations in the fall of 1971 but were reactivated in late 1973 after sampling was completed. A few pulp and paper mills are concentrated around the three centers of Campbellton, Bathurst and Newcastle. There are also a few small chemical industries in the region.

In the normal mining operation in the area, the three main waste components (mine drainage, mill-process effluent and contaminated surface drainage) are mixed for primary treatment in tailing ponds. The resulting effluent is partially reclaimed as mill feed water in some instances, and the rest is discharged into nearby streams. However, despite recent improvements in the treatment of mining effluents, considerable quantities of metals in low concentrations still find their way into the receiving streams and thus constitute a source of pollution. One of the main problems in monitoring trace-metal contents of surface waters is their high degree of fluctuation, owing to sudden changes in precipitation, soil conditions and other causes. However, aquatic sediments have been used as a guide to detect metal contamination, since it is recognized that trace-element deposition in sediments is an integral part of the cycling of elements; and therefore the sediments reflect the nature of overlying waters at the time of deposition.

The area of study comprised three main salmon-bearing rivers, the Restigouche, Nepisiguit and Miramichi, whose water quality has deteriorated recently owing to extensive mining activities in their catchment areas. These rivers suffer from three major, but closely related, sources of pollution arising from mining operations in the area: viz. (1) water either overflowing or drained from abandoned open pits, (2) surface drainage and leaching from uncovered ore reserves and from tailings stored in the drainage area, and (3) the release of effluent from the base-metal concentration process into river systems.

The Nepisiguit River and Little River receive the effluents discharged directly from Brunswick No. 6 and No. 12 mines, respectively—the former river through its tributary, Knight Brook. The Miramichi River receives the effluent from Heath Steele Mine through its South Tomogonops tributary. At present, there is no mining activity in the Restigouche basin.

EXPERIMENTAL METHODS

Sediment samples were collected in the study area (Fig. 1) in July, 1973, with a galvanized steel Ponar dredge. In order to reduce the possibility of contamination from the dredge itself, a quantity of sediment was taken from the centre of each sample and the rest of the sample was discarded.

The wet samples were allowed to air-dry on petri dishes for a few days. Analyses were done on a portion of sediment which passed through a standard, no. 10 seive.

The sample was digested with HCl-HNO_3 (3:1) for about two hours. The solution was then diluted with water and boiled further to expel all the digestion gases and to dissolve all soluble material. It was then cooled, filtered through Whatman no. 42 filter paper and made to volume for final analysis.

Analysis was carried out using an atomic absorption spectrometer by conventional flame technique. The calibration matrix consisted of copper, zinc, cadmium, lead and iron.

All glassware, filter paper, and other apparatus were washed with nitric acid before use. The acids used were Aristar grade (B.D.H. Ltd., Poole, England) and the distilled water was further purified by passing through a Milli-Q-system.

A Perkin-Elmer Model 503 atomic absorption spectrometer, equipped with a simultaneous deuterium background corrector, was used for the metal analysis. Instrument parameters used were as given in the Perkin-Elmer (1973) handbook. Cadmium and lead were analysed by solvent extraction, using ammonium-1-pyrrolidinedithio-carbamate (APDC) as the complexing agent in methyl isobutyl ketone (MIBK).

RESULTS AND DISCUSSION

It was reported earlier (Boyle et al. 1966) that in the Bathurst area the freshwater sediments have an average background level of 150 ppm zinc and 25 ppm lead; though individual values in the range of 10-34,000 and 5-3,300 ppm, respectively, were observed. Similarly, the copper background level was found to be about 12 ppm, with a range of 4-4,000 ppm in different streams. Cadmium data were not available. Near known ore deposits, the values were generally high, but diminished downstream. Again, higher-than-average contents of zinc were correlated with higher-than-average contents of lead and copper.

In the current studies (Table 1), the general trends of previous observations have been sustained, except in a few cases, where anomalous levels of the heavy metals were observed. Comparative heavy-metal concentrations in selected harbour sediments of the Maritimes area have been determined (Table 2). Average concentrations of all metals are much the higher in the Nepisiguit.

In the Nepisiguit River, the concentrations of metals at Site 2 are, respectively, much lower than at sites above or below it (Table 1, Fig. 2 and Fig. 5), possibly because this site is close to the mouth of the unpolluted Tetagouche River. However, Sites 1 and 3, which are also close to the Tetagouche, had somewhat higher levels of metals.

The concentrations of all metals at Sites 7, 8 and 9 were significantly higher than at most other sites. The only exceptions to this rule were Sites 3, 4 and 5, with high lead concentrations, and Site 10, with a high copper concentration (Table 1, Figs. 5 and 6).

TABLE 1. Heavy-metal concentration in northeastern New Brunswick sediment samples, July, 1973.

Location		Concentrations (µg/g) (air dry)			
River	Site no.	Cu	Zn	Pb	Cd
Nepisiguit	1	13	146	20	0.88
	2	5	82	10	0.52
	3	19	146	26	0.95
	4	21	206	39	1.19
	5	15	163	27	0.96
	6	34	391	8	1.98
	7	65	520	36	3.76
	8	63	437	23	2.76
	9	80	438	24	2.56
	10	69	84	8	0.42
	11	12	117	11	0.67
Miramichi	1	9	84	11	0.53
	2	6	72	9	0.51
	3	5	65	9	0.61
	4	10	104	15	0.94
Restigouche	1	9	49	13	0.60
	2	6	53	11	0.56
	3	11	48	16	1.07

TABLE 2. Heavy-metal concentration in some harbour sediments in the Maritimes, 1973.[1]

Location	Sample no.	Concentrations (µg/g, dry weight)		
		Cu	Zn	Pb
Canso, Nova Scotia	1	4	27	–
	2	4	24	–
	3	22	16	–
	4	10	50	–
Summerside, Prince Edward Island	1	13	55	8
	2	14	58	6
	3	7	47	9
Dalhousie, New Brunswick (Dredge)	1	3	15	5
	2	9	29	–
	3	5	18	4

[1]Data from personal communication, Environmental Protection Service, Halifax, N.S.

Copper

Copper has been found in non-industrial stream sediment in a range of concentrations from 3.5 to 11.2 ppm (Collinson and Shimp 1972). In the Ottawa and Rideau rivers, concentrations were 26.0 and 20.0 ppm, respectively (Oliver and Agemain 1974).

The Nepisiguit River sediment shows a much higher average copper level (36.0 ppm), while samples from the Miramichi and Restigouche (Table 1, and Figs. 3, 4, 7 and 8) are within the normal range. Sites located on the main Nepisiguit River are much higher in average copper concentration (61 ppm) than those in the Little River (18 ppm).

Zinc

Zinc levels in the Ottawa and Rideau rivers are in the range of 138 and 118 ppm, respectively (Oliver and Agemain 1974). In the lake sediments of the Yellowknife area, zinc has been found at low concentrations of about 65 ppm (Falk et al. 1973).

The Nepisiguit River has a much higher average zinc level; and again, the two channels show their respective distinctive patterns. The main river has an average of 447 ppm, whereas the Middle River estuary has 171 ppm.

Miramichi and Restigouche river sediment samples have fairly low average zinc levels of 81.0 and 50.0 ppm, respectively, and are possibly the background levels at present.

Lead

Lead concentrations have been found in the range of 12-27 ppm in non-industrial stream sediments (Collinson and Shimp 1972). In the Ottawa and Rideau rivers, background levels were 46 and 62 ppm, respectively (Oliver and Agemain 1974). These unusually high levels were attributed to snow-dumping operations in the river.

The average lead level in Bathurst Harbour is 21 ppm. However, the Nepisiguit River and Middle River estuary levels are 23 and 31 ppm, respectively, which is exactly the reverse of the copper and zinc levels in these two rivers. Since Little River receives the mining effluent from Brunswick No. 12 operations, and with the knowledge that lead is least mobile compared to other elements because of its solubility properties, these results are not so anomalous as they at first seem.

Cadmium

The mean cadmium levels in the Ottawa and Rideau river sediments are 0.45 ppm and 0.46 ppm, respectively. Vinogradov

(1959) and Warren et al. (1971) set the maximum acceptable levels in sediments at 0.5 ppm.

In the Nepisiguit River, the average is 1.51 ppm, and all sites excepting Site 10 exceed the acceptable level. In fact, two-thirds of the sampling sites have cadmium levels far in excess of the acceptable maximum, and should be considered as extremely dangerous.

In the case of the Miramichi and Restigouche, one site in each river shows cadmium content much in excess of the acceptable level (Table 1 and Figs. 7 and 8). Owing to an insufficient number of sampling sites, a qualitative picture only can be derived. However, it is of utmost importance that the discharge level be kept to a minimum.

Average heavy-metal contents of the three rivers are compared with those of Ottawa and Rideau river sediments, which are considered to be polluted, at least in certain locations (Table 3). However, direct comparison of the metal contents in these rivers with the Ottawa and Rideau rivers would be unwise, since the latter were analysed on the -80 mesh fraction (180 μm), whereas the data in this study are based on a -10 mesh fraction (2.00 mm). It is known that finer sediment samples contained more heavy metal than did coarse materials. Consequently, the values of the Ottawa and Rideau rivers would be expected to exceed those from the three New Brunswick rivers. However, the sediments from the Nepisiguit exceeded those from the Ottawa and Rideau in copper and zinc, and samples from all three New Brunswick rivers exceeded those from the Ottawa and Rideau in cadmium.

TABLE 3. Mean background concentration of heavy metal in river sediments.

	Mean Concentration (ppm)				
Heavy metal	Ottawa[1] River	Rideau[1] River	Nepisiguit River	Miramichi River	Restigouche River
Cu	26	20	33	7.4	9
Zn	138	118	188	81	50
Pb	46	62	19	11	13
Cd	0.45	0.46	1.51	0.65	0.74

[1]Oliver and Agemain 1974.

The receiving-stream water quality was investigated in order to understand the unusually high metal content of the Nepisiguit River sediments as opposed to those of the Miramichi and Restigouche rivers. Pertinent water-analysis values were

collected from a survey conducted in 1973 (Environment Canada, 1974) (Appendices A, B and C). Copper, zinc and cadmium contents of the two channels of Bathurst Harbour closely parallel the metal content of the two streams: viz., metal content in Nepisiguit River channel is higher than the other. However, the lead content of the Middle River estuarial sediments is proportionally higher, and reflects the high level of lead in the effluent from Brunswick No. 12 mining operations.

It is well known that though most of the elements are deposited in the sediments, they then enter the food chain and are passed along to fish and shellfish. Recently, Delisle et al. (1975) have demonstrated direct uptake of heavy metals by fish from sediments, without the intermediate food-chain mechanism.

In view of the above results, it can be concluded that the concentrations of metals in Nepisiguit River surficial sediments parallel the concentrations of metals in the receiving streams and may be hazardous to the aquatic ecosystem. The effluent should be closely controlled to prevent any further increase in concentration levels in the sediments. If this can be achieved, it is hoped that most of the metals will ultimately dissipate in the ocean water.

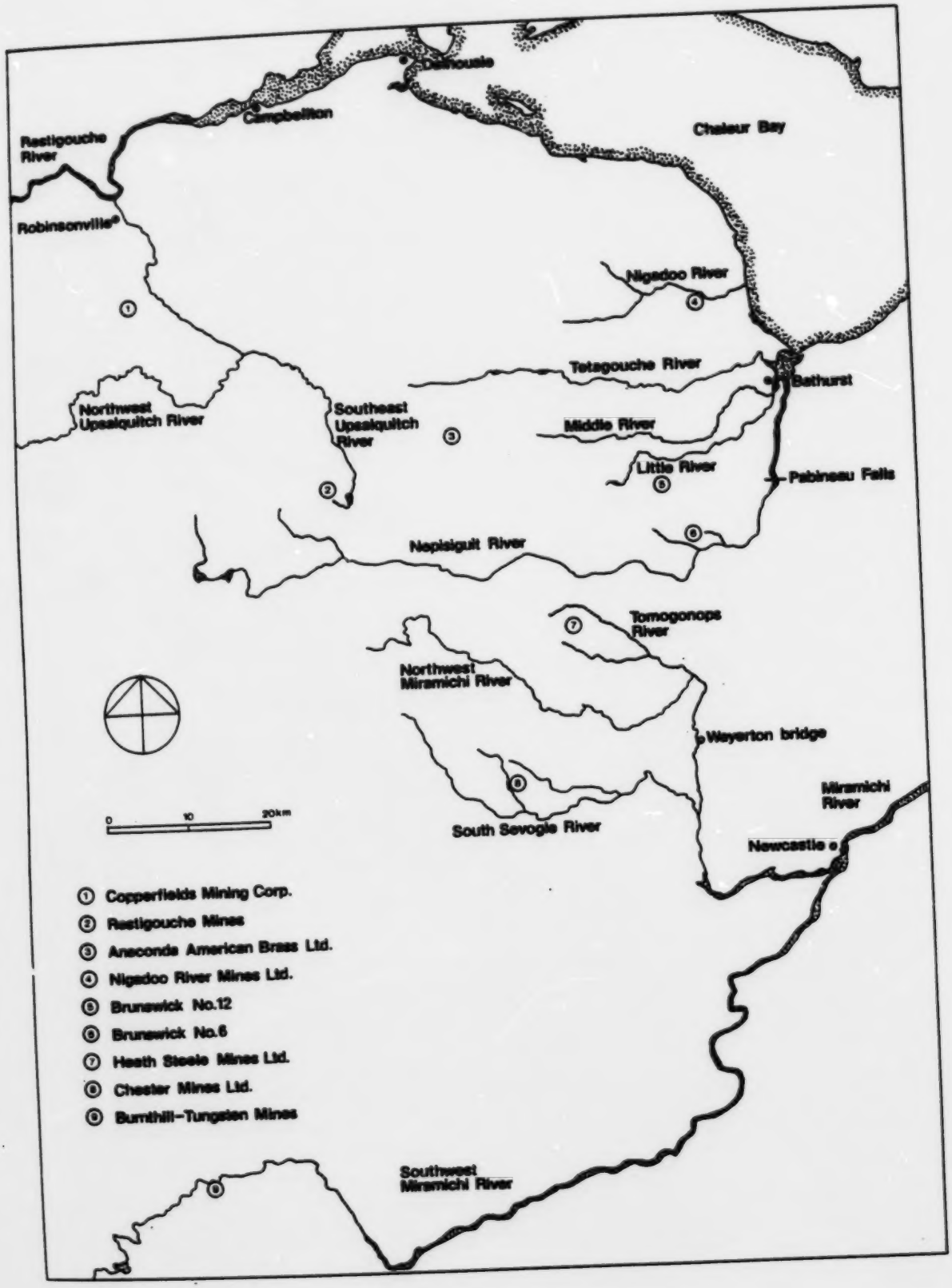

FIG. 1. Study area of northeastern New Brunswick.

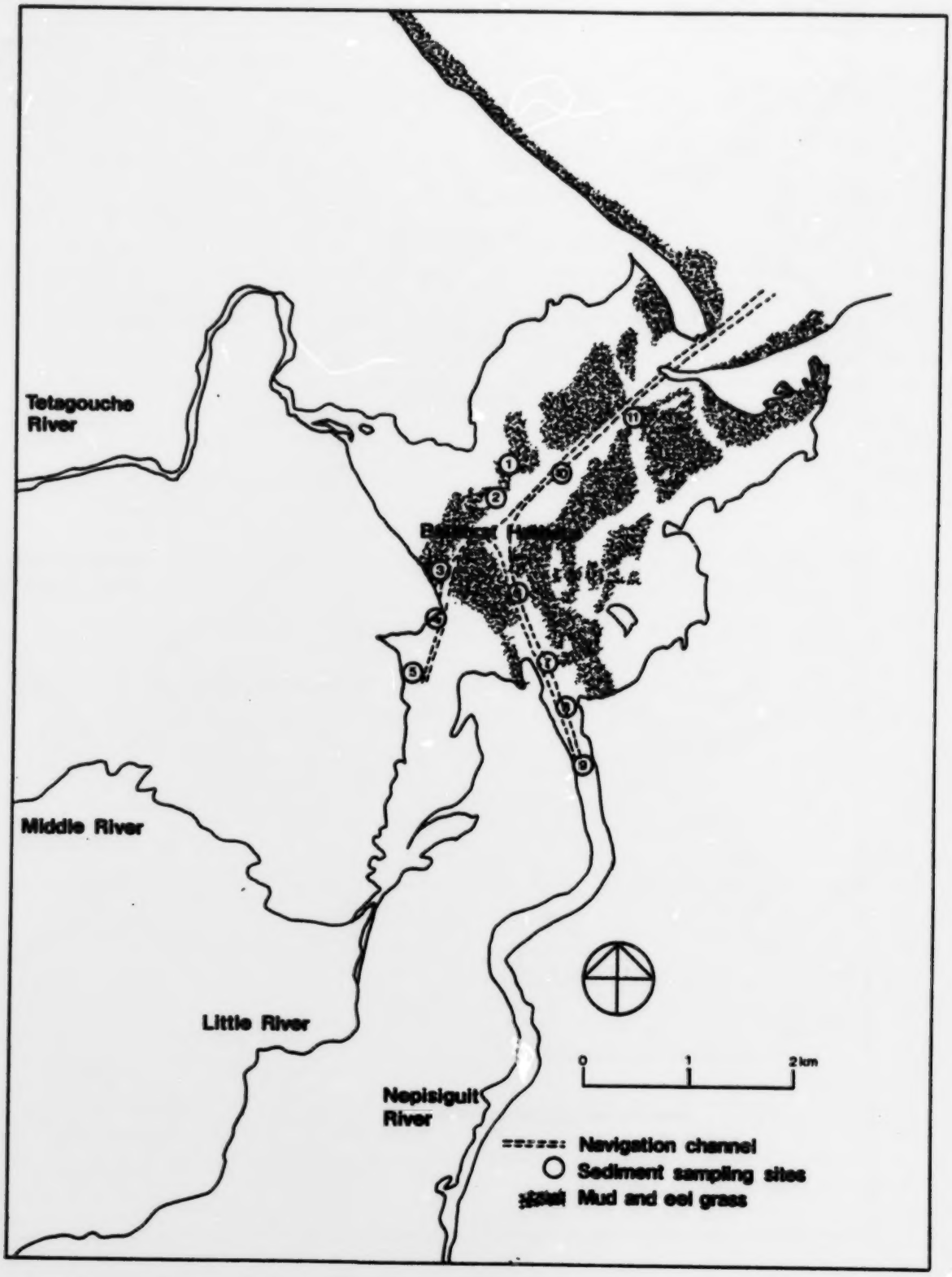

FIG. 2. Sampling sites in Nepisiguit River.

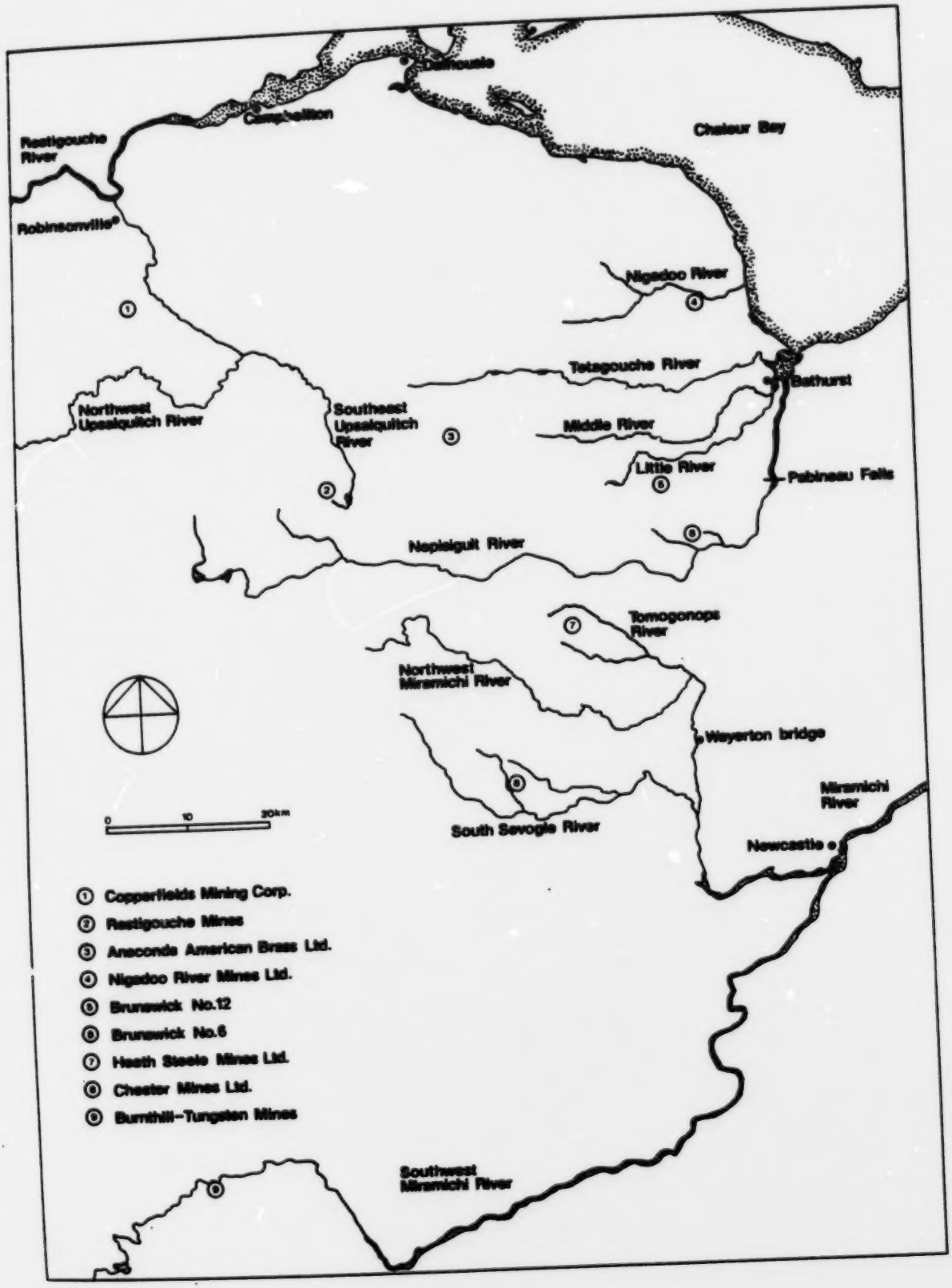

FIG. 1. Study area of northeastern New Brunswick.

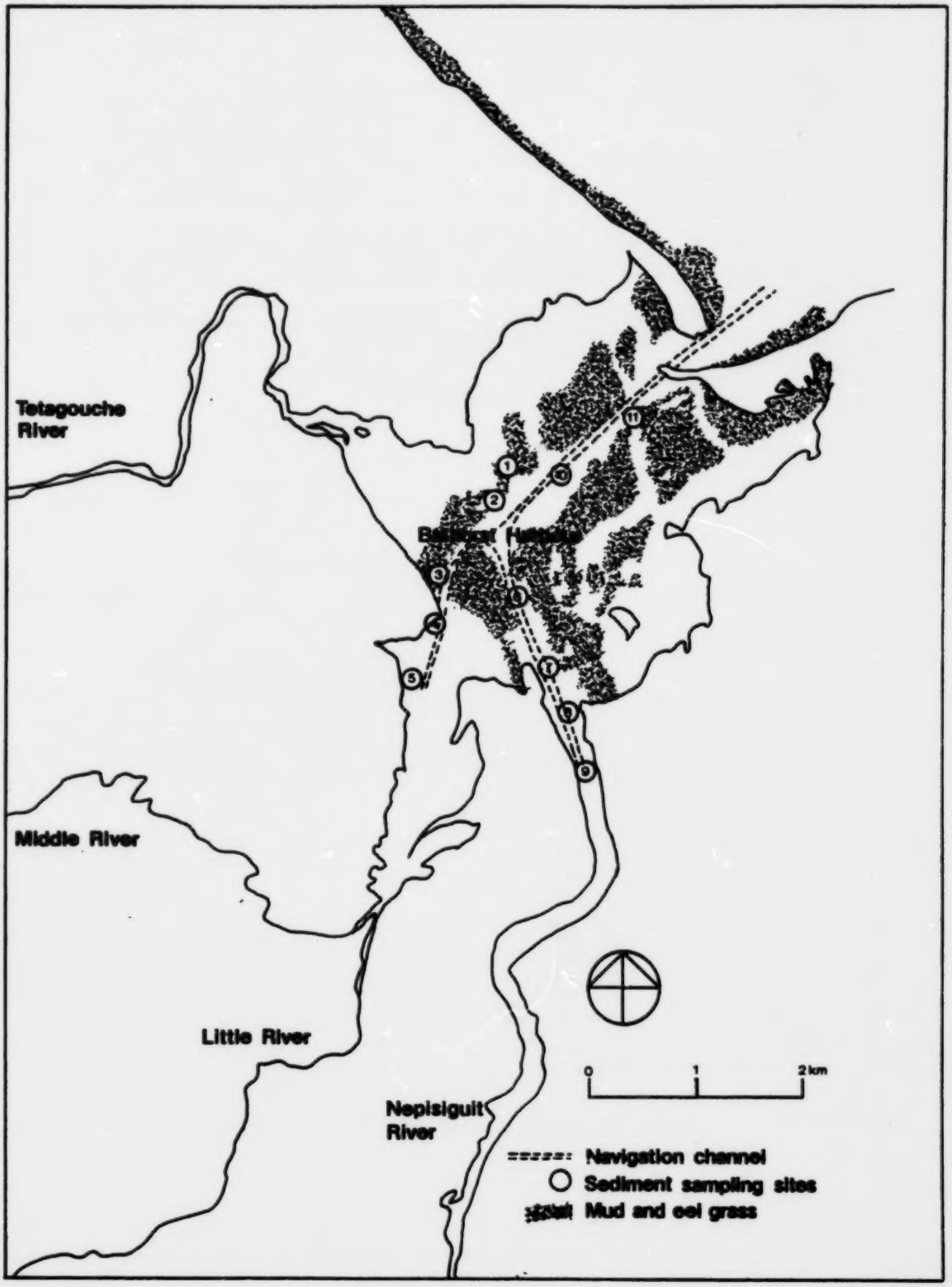

FIG. 2. Sampling sites in Nepisiguit River.

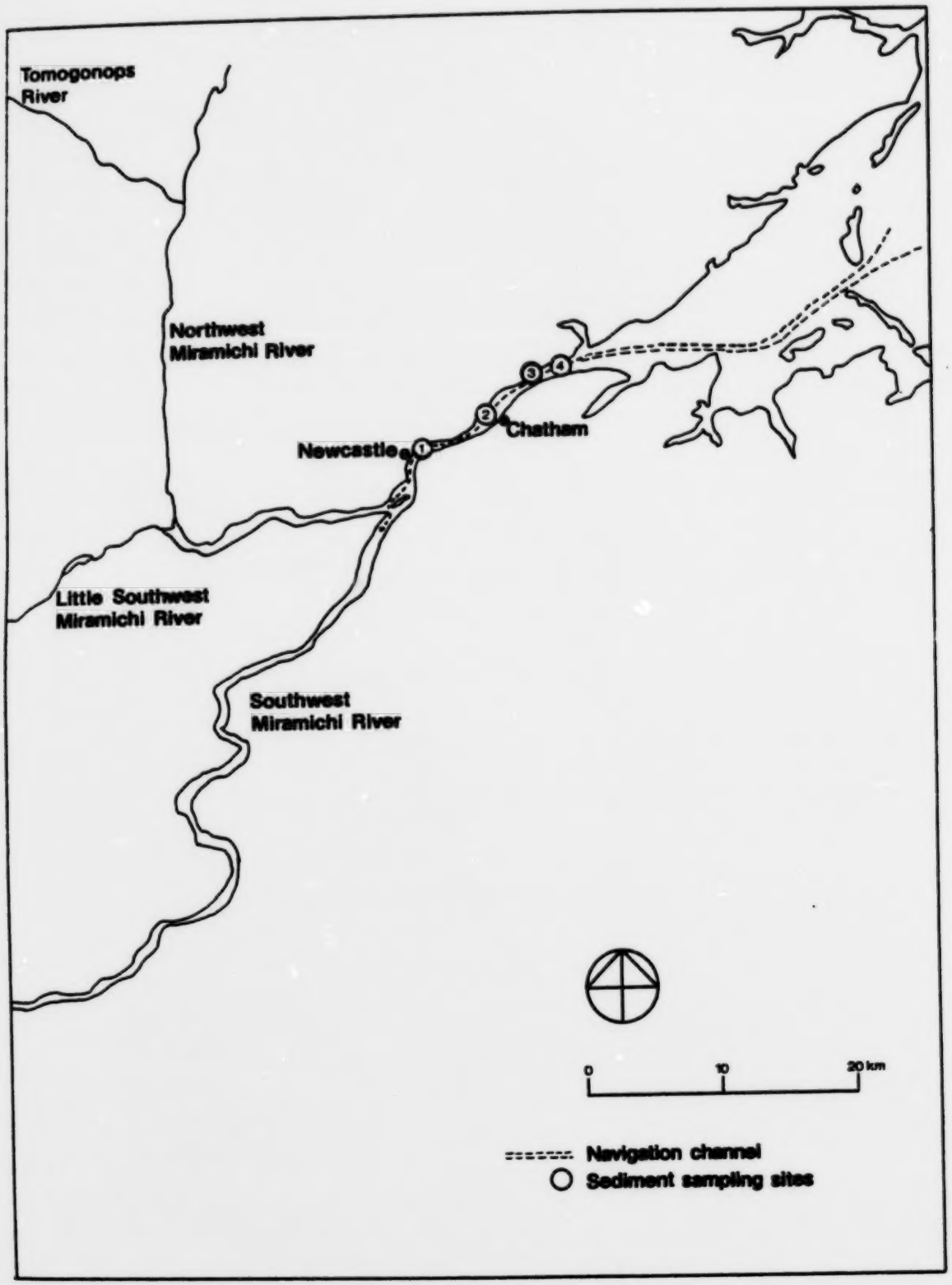

FIG. 3. Sampling sites in Miramichi River.

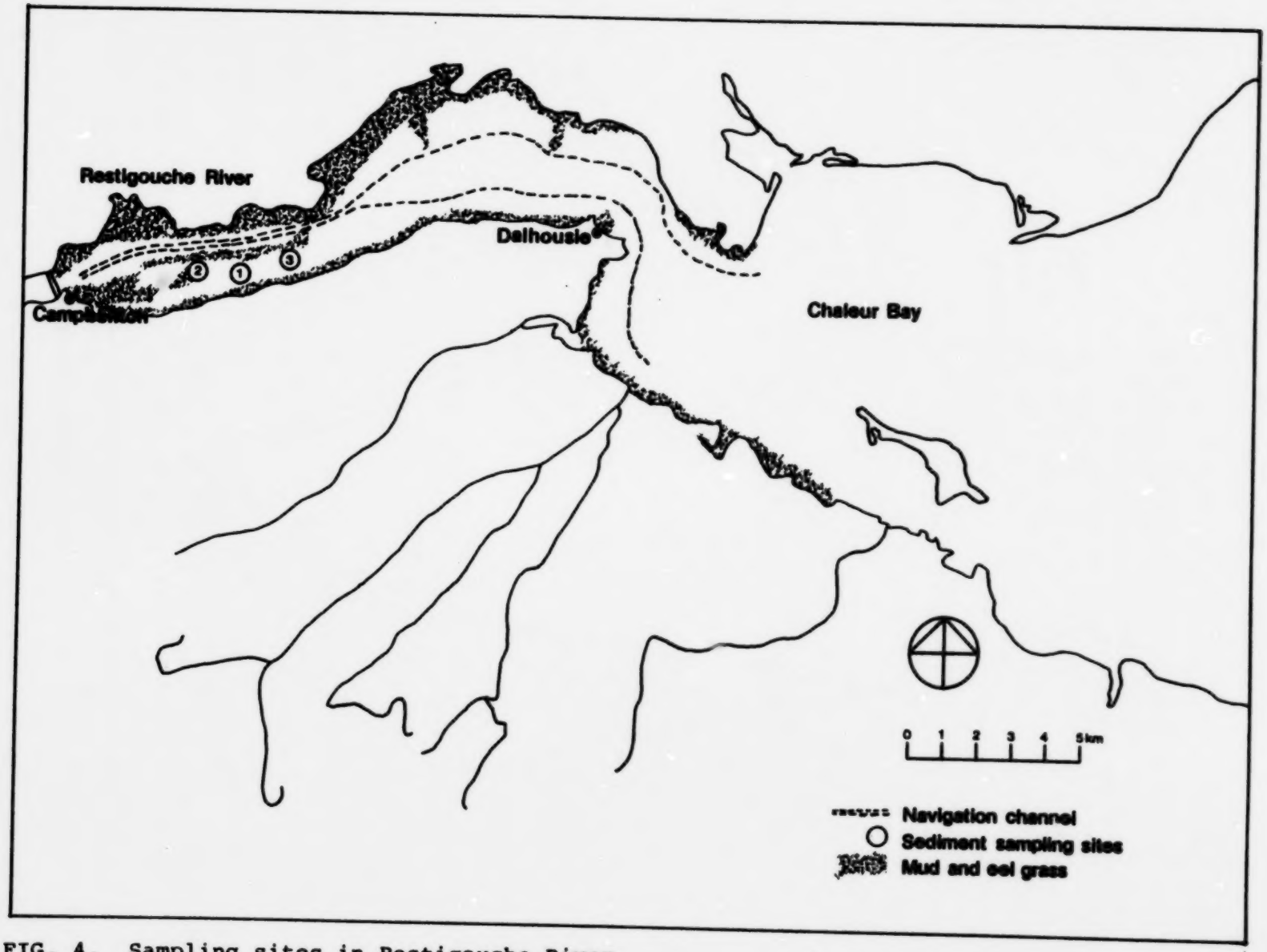

FIG. 4. Sampling sites in Restigouche River.

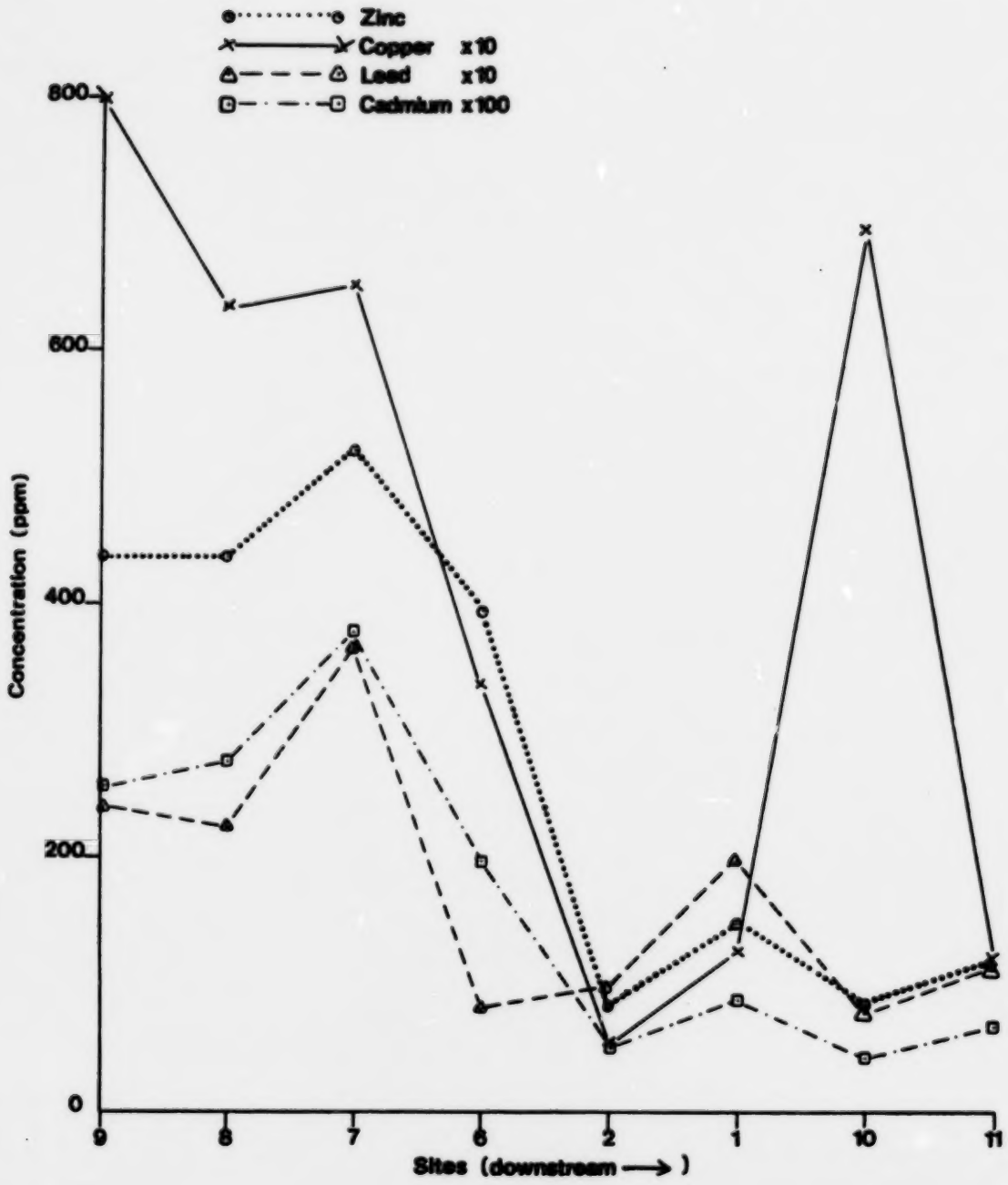

FIG. 5. Concentration of heavy metals in Nepisiguit River.

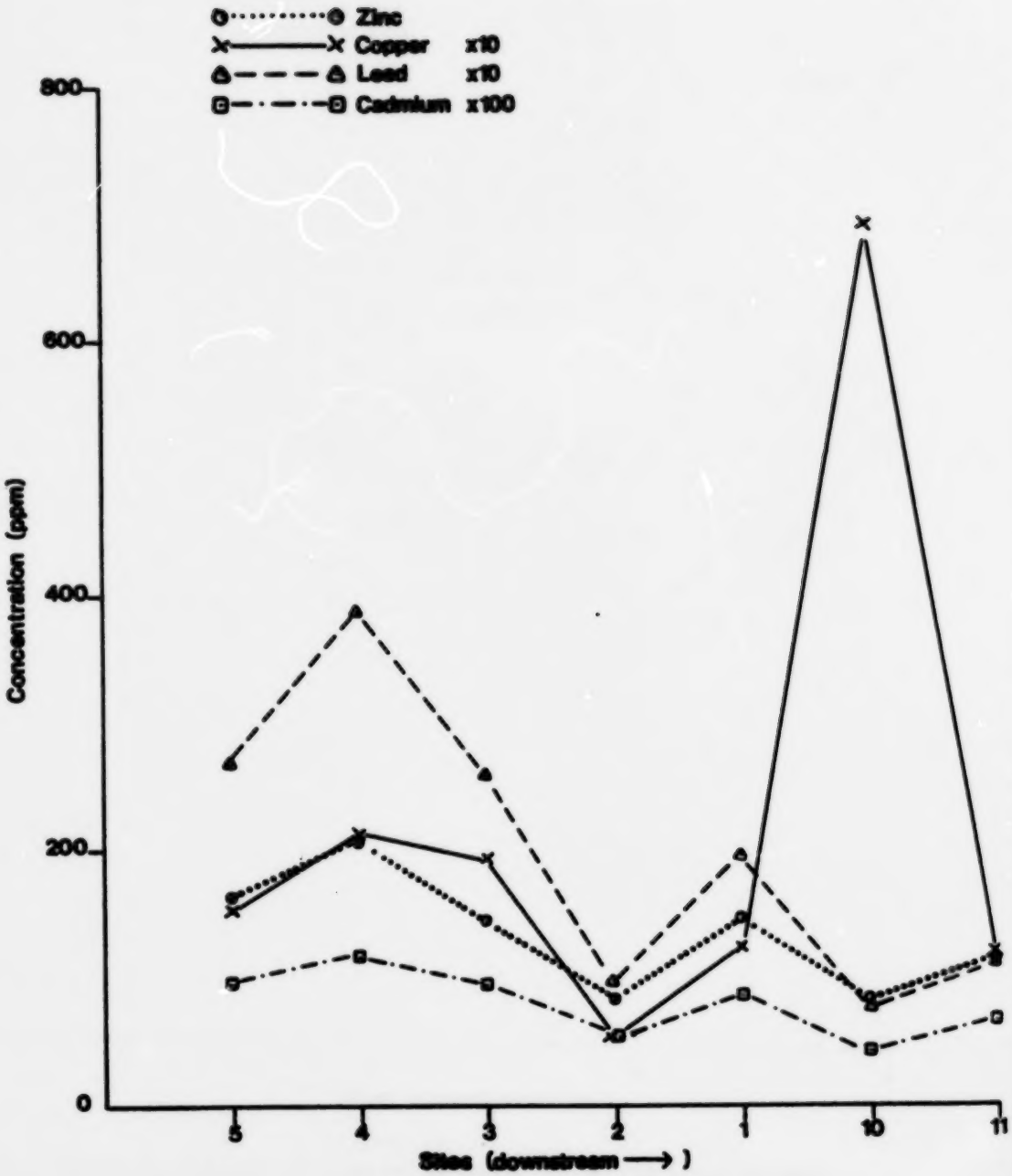

FIG. 6. Concentration of heavy metals in Middle River.

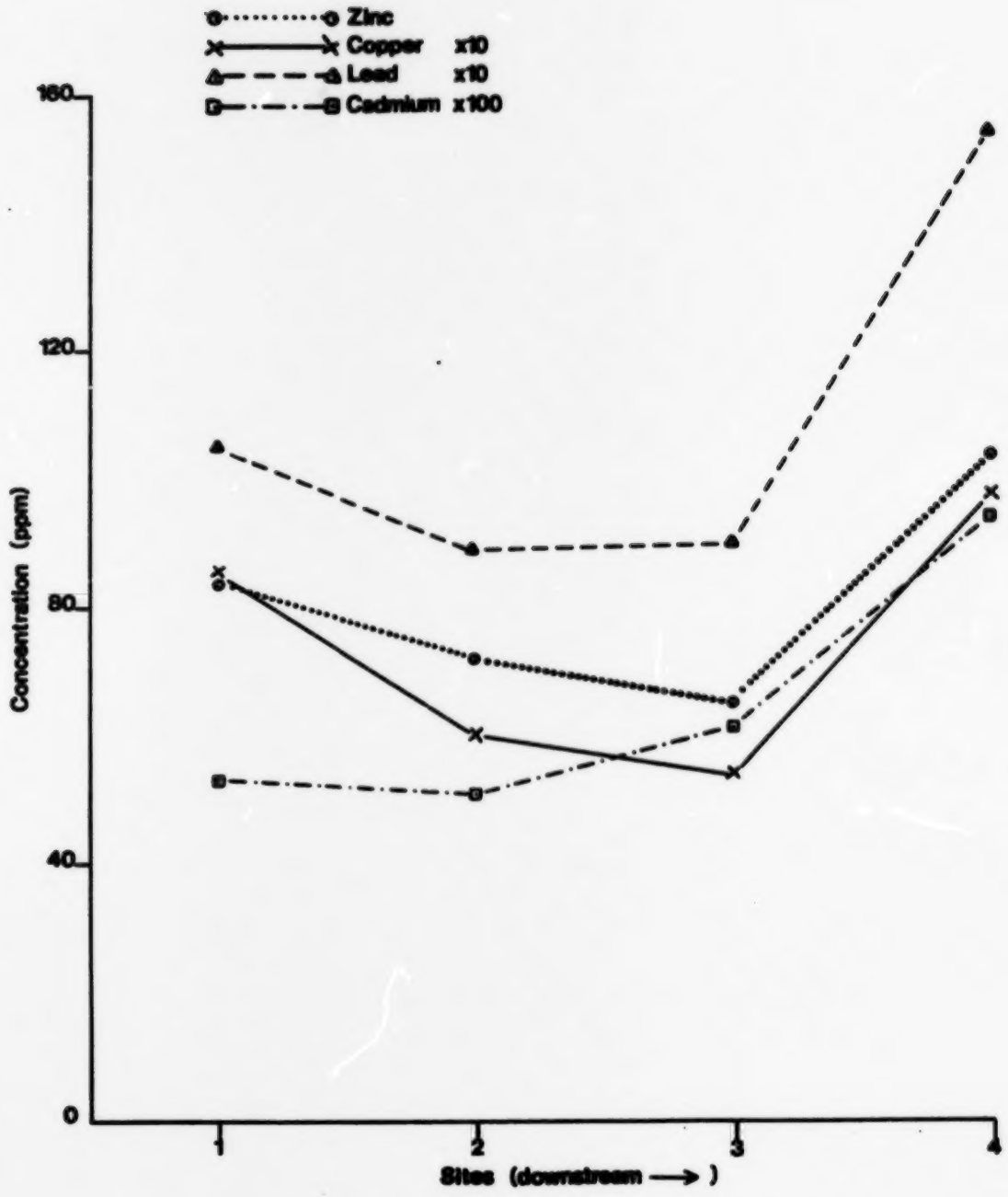

FIG. 7. Concentration of heavy metals in Miramichi River.

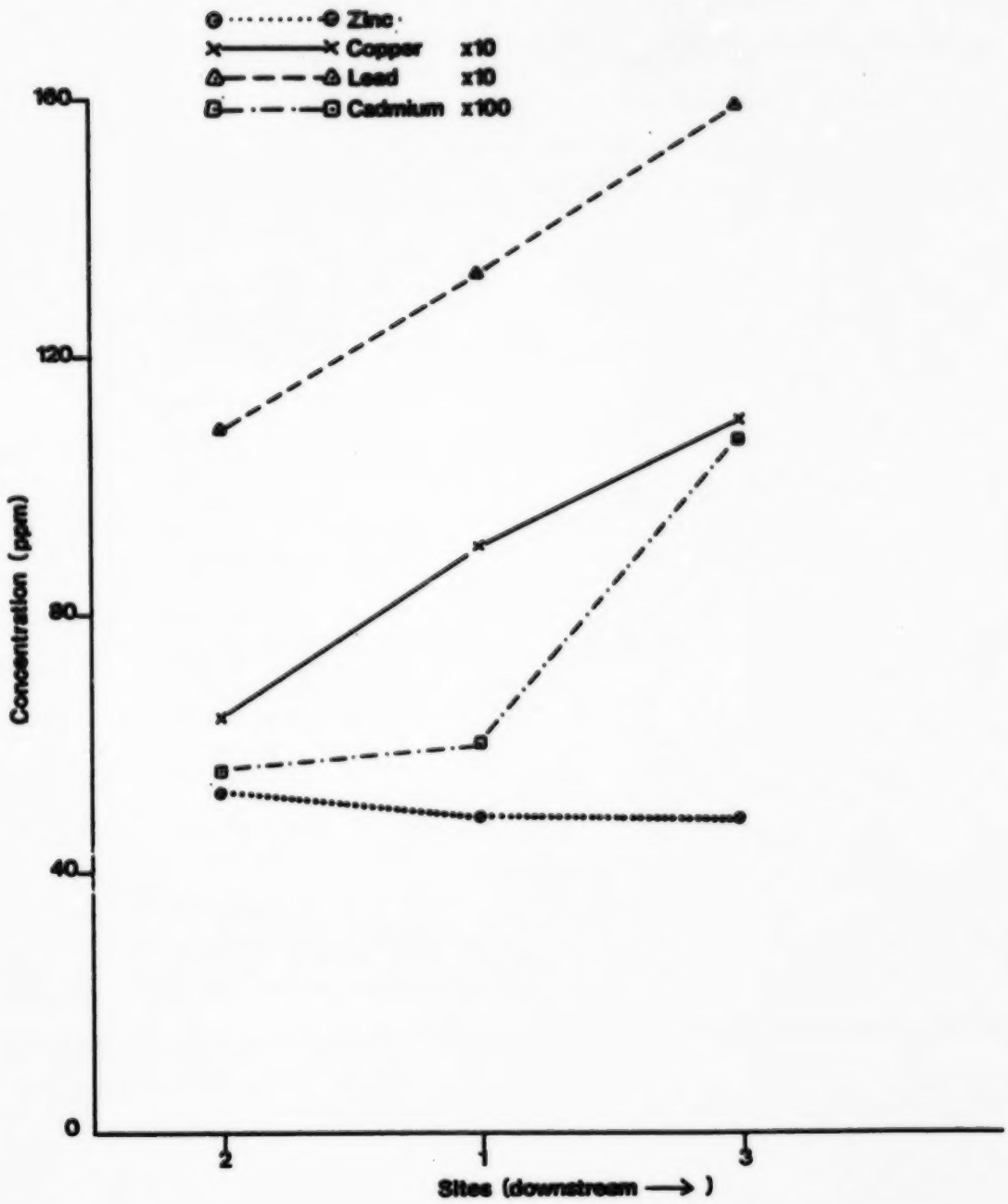

FIG. 8. Concentration of heavy metals in Restigouche River.

APPENDIX A

HEAVY METAL CONCENTRATION IN RECEIVING STREAMS OF NEPISIGUIT RIVER BASIN

Site no.	Mine and receiving stream site location	Metal level (µg/l) Cu	Zn	Pb	Cd
	Anaconda American Brass Ltd. (Forty Mile Brook)				
AB-1	1/2 mi above mine	3	2	3	<1
AB-6	Below mine	56	865	4	–
AB-4	50 ft above mouth at Nepisiguit River	10	80	3	<1
AB-7	Nepisiguit River, 2 mi below Forty Mile Brook	5	44	4	<1
	Brunswick No. 12 (Little River)				
B-7	Little River (control)	2	9	6	<1
B-6	South Little River, below mine	22	1,930	1,030	1
B-8	Little River, above Bathurst appox. 1 mi	11	4,150	60	–
	Brunswick No. 6 (Nepisiguit River)				
B#6-8	Nepisiguit, 100 ft above mouth of Austin Brook	3	58	5	1
B#6-9	Nepisiguit River, below Knight Brook	56	1,210	6	2
B#6-14	Nepisiguit River, Pabineau Falls	6	150	5	–
B#6-16	Nepisiguit River, Bathurst at Irving Pier	7	130	5	–
	Nigadoo River Mine (Nigadoo River)				
Nig. 3	1/4 mi above mine area	2	6	4	<1
Nig. 4	1 mi below mine area	2	13	5	1

APPENDIX B

HEAVY METAL CONCENTRATION IN RECEIVING STREAMS OF MIRAMICHI RIVER BASIN

Site no.	Mine and receiving stream site location	Metal level (µg/l) Cu	Zn	Pb	Cd
	Heath Steele (South and Little South Tomogonops River)				
H-12	Little South Tomogonops River, above mine	2	15	9	1
H-3	South Tomogonops River, below tailings pond	4	73	11	<1
H-17	Tomogonops River at mouth, 50 ft above junction of Tomogonops and N.W. Miramichi	16	225	6	<1
H-21	N.W. Miramichi, below mouth of Tomogonops at Wayerton Bridge	2	26	5	–
	Burnthill - Tungsten (Southwest Miramichi)				
BT-1	S.W. Miramichi, 3 mi above mine	2	21	4	<1
BT-5	S.W. Miramichi, 5 mi below mine	2	11	3	–
	Chester Mines Ltd. (South Sevogle River)				
C-1	Clearwater Stream, 1/4 mi above mine	2	11	2	–
C-7	South Sevogle River, below mine above Sheephouse Brook	2	5	3	–
C-8	South Sevogle River, below mouth of Sheephouse Brook	2	8	2	<1

APPENDIX C

HEAVY METAL CONCENTRATION IN RECEIVING STREAMS OF RESTIGOUCHE RIVER BASIN

Site no.	Mine and receiving stream site location	Metal level (µg/l) Cu	Zn	Pb	Cd
	Copperfields Mining Corp. (Upsalquitch River)				
CMC-1	Northwest Upsalquitch River, above mine	2	13	4	–
CMC-5	Upsalquitch River, below mine	3	19	4	–
CMC-7	Upsalquitch River, at Robinsonville	5	467	14	–
	Restigouche (Formerly Tech. Corp.)(Southeast Upsalquitch and Nepisiguit rivers)				
R-1	Above mine, Upsalquitch River	2	6	2	–
R-5	Below mine, mouth of Portage Brook	2	16	3	1
R-7	Nepisiguit River	2	7	4	–

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POOR

QUALITY

ORIGINAL